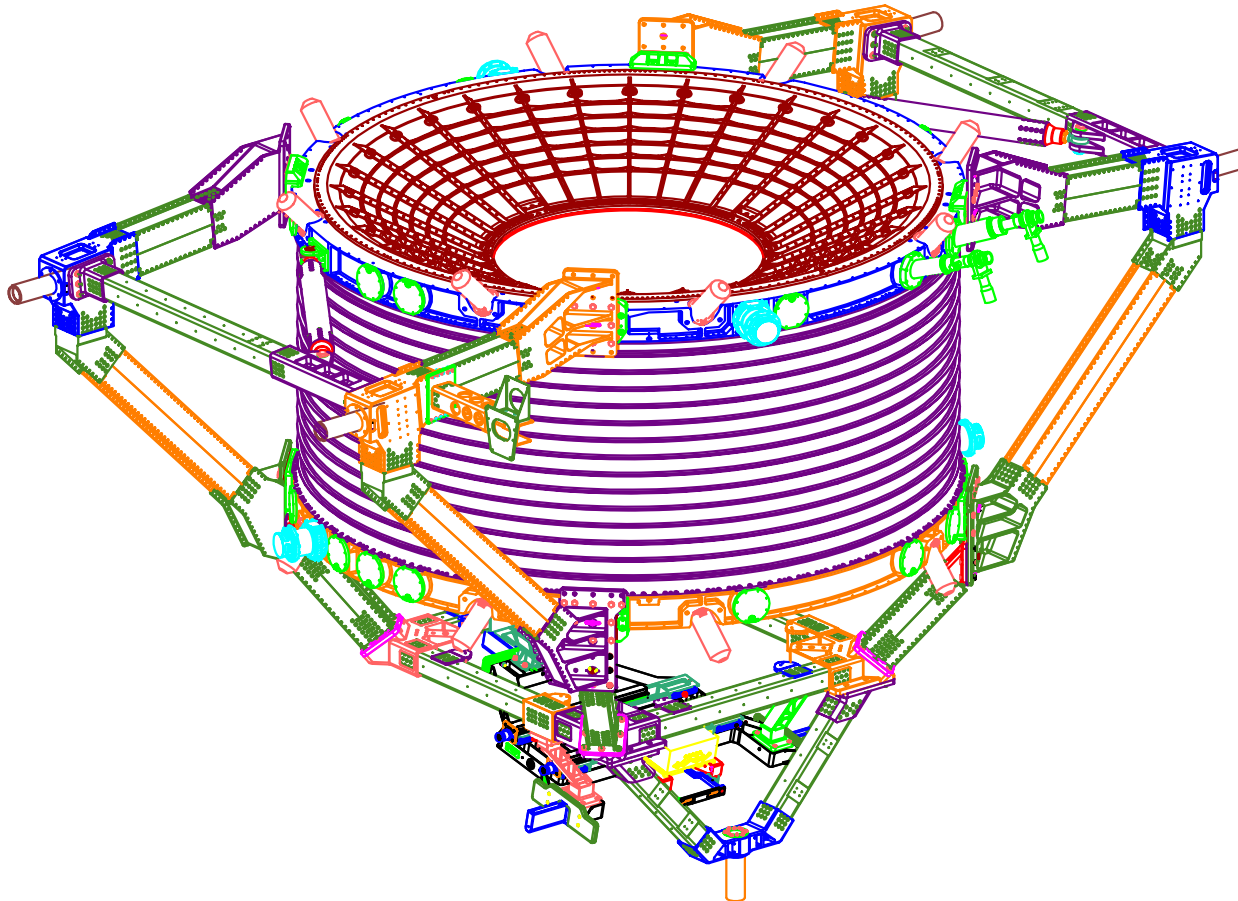


# AMS-02 Critical Design Review

## **AMS-02 Payload Integration Hardware Stress Analysis**

# AMS 02 Integration Hardware

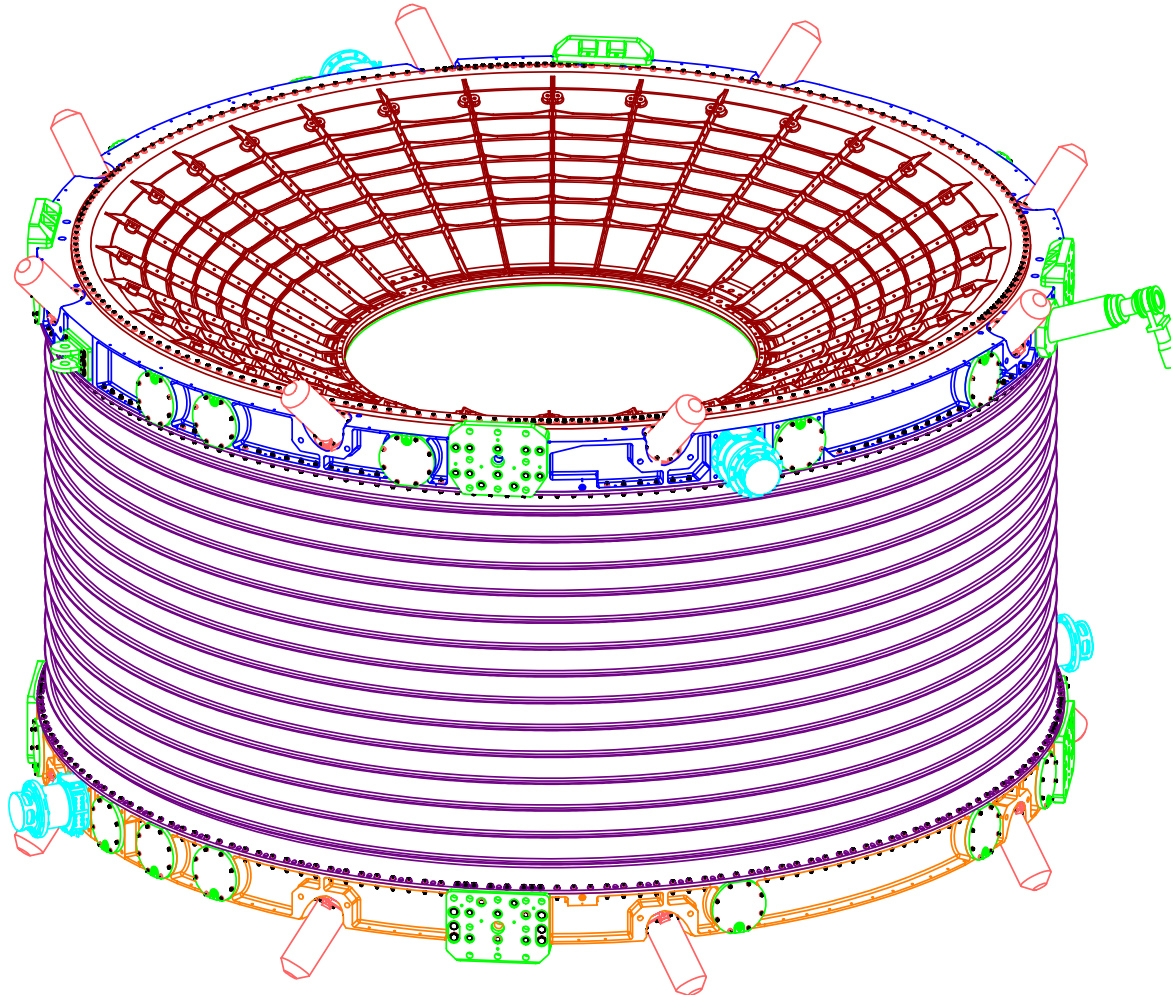


# AMS-02 Integration Hardware (Cont)

## Stress Analysis

- **Stress analysis of all components are performed as per JSC 28792 (AMS-02 Structural Verification Plan)**
- **Appropriate Factors of safety as per JSC 28792 Appendix A have been used**
- **For combined loads interaction formulas are used based on stress ratios for each type of loading**
- **Material properties for metallic materials are taken from MIL-HDBK-5H**
- **Temperature reduction factors are applied as required**
- **Margins of safety for all structural components are greater than zero for all combined load conditions**

- Vacuum Case



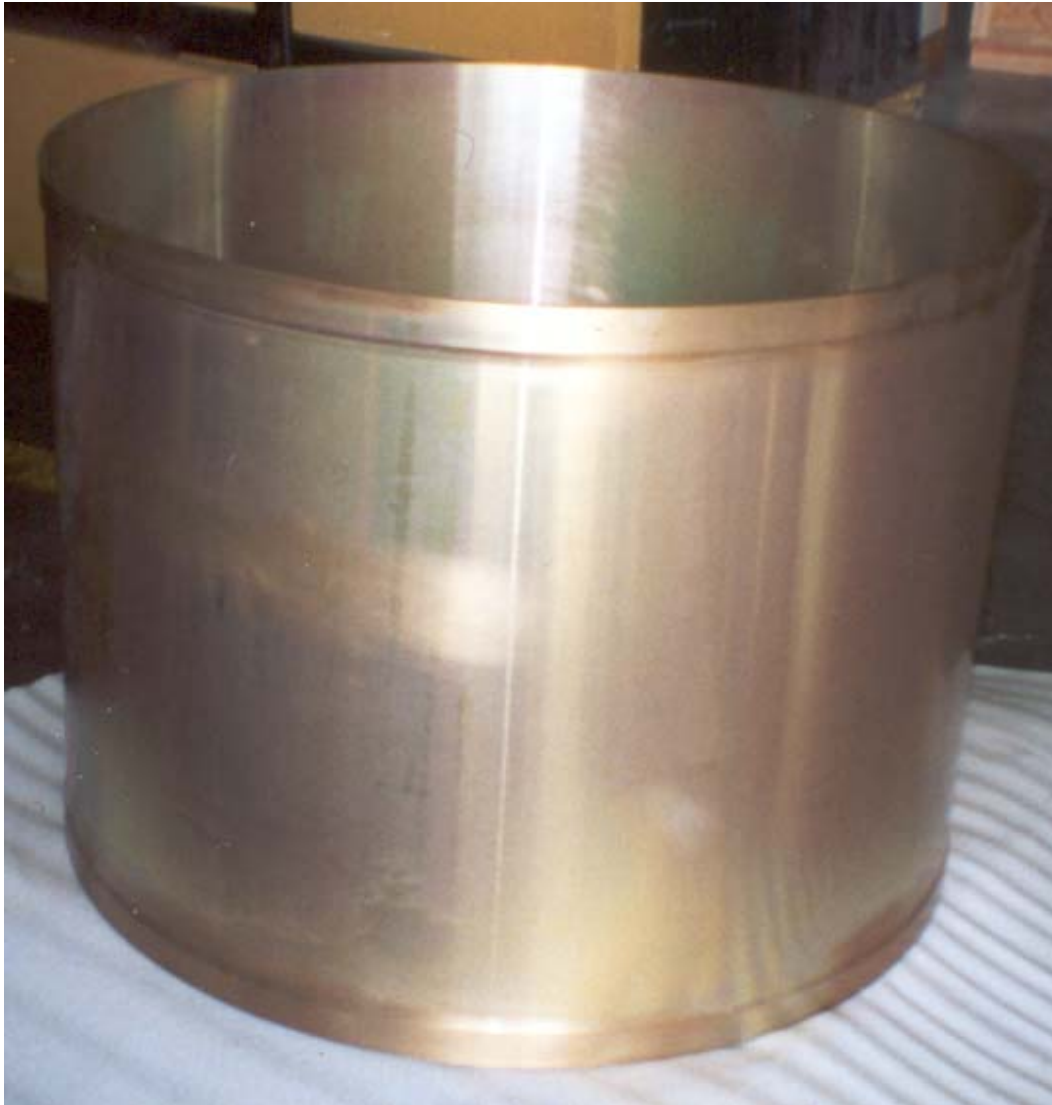
# AMS-02 Integration Hardware (Cont)

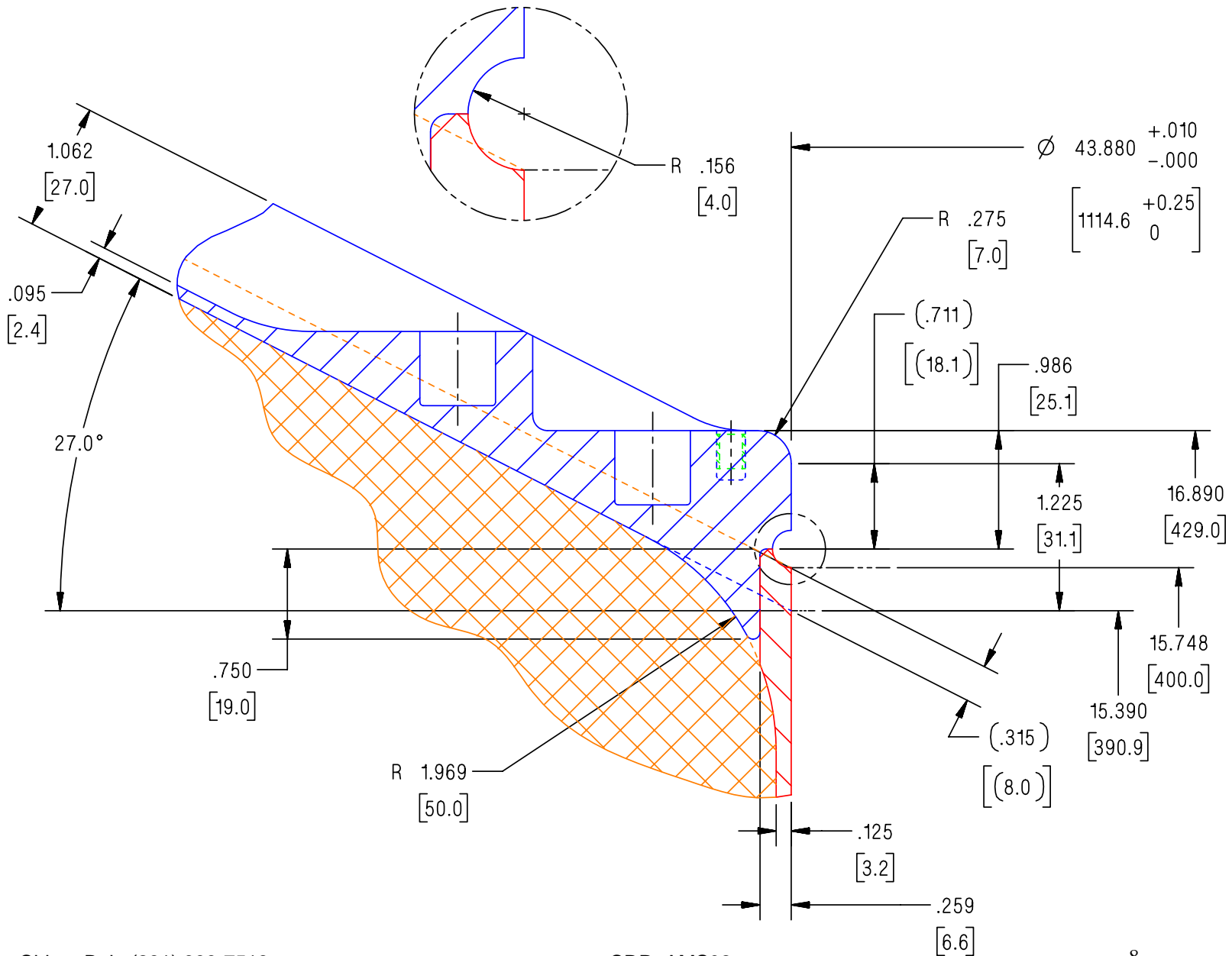
- **Vacuum Case (cont)**
  - **Vacuum Case consists of the following Components:**
    - **Inner Cylinder**
    - **Conical Flanges**
    - **Support Rings**
    - **Outer Cylinder**
    - **Interface plates**
    - **Diagonal strut clevis**

# AMS-02 Integration Hardware (Cont)

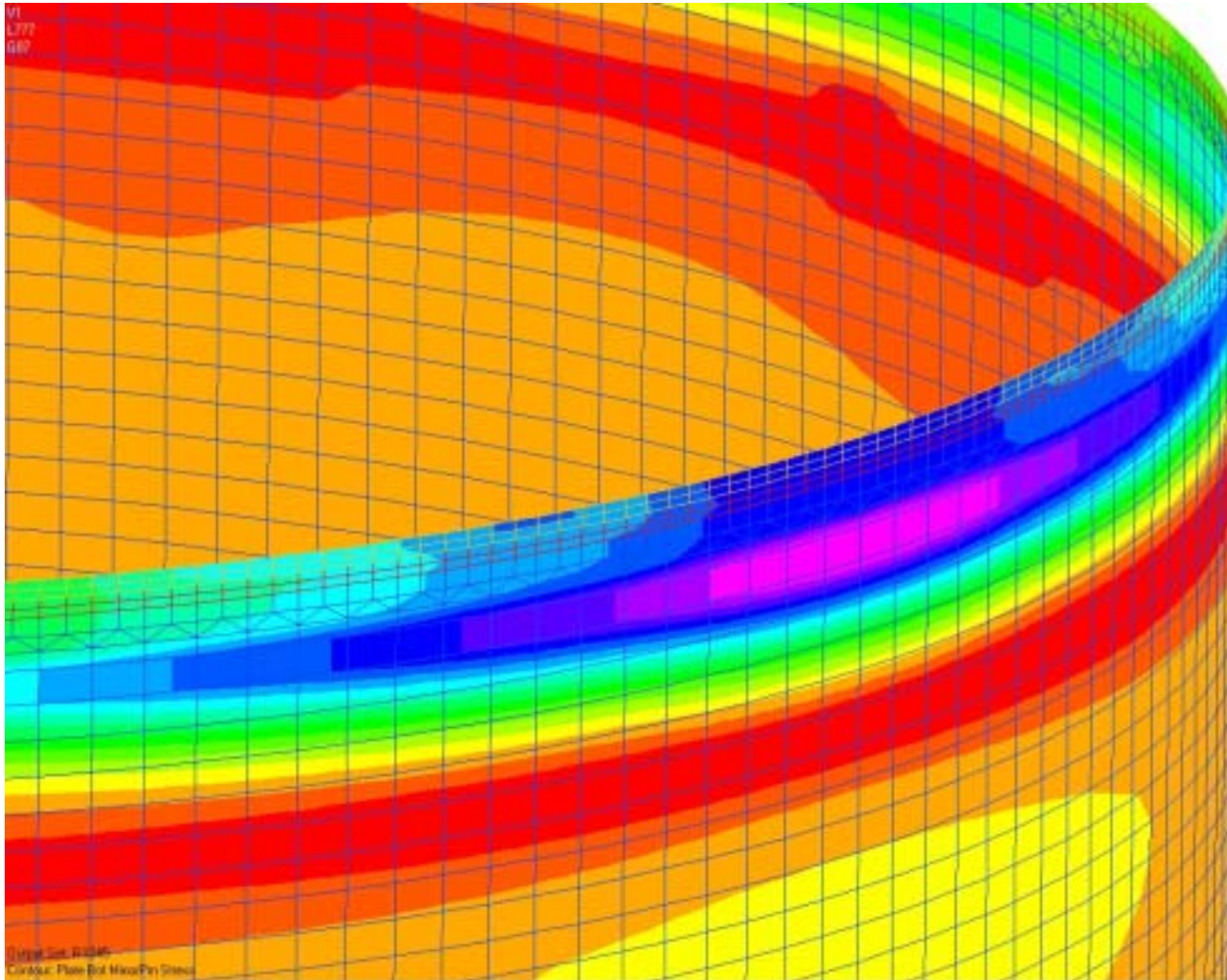
- **Inner Cylinder**

- **Monocoque cylinder 44.398 in diameter 0.125 in. thick**
- **Top and bottom ends are 0.259 in thick for welding to the conical flanges**
- **Material 2219-T852 Ring forging**
- **Close out weld is full penetration gas Tungsten Arc weld**
- **Minimum ultimate Margin of Safety**
  - **Inner Cylinder 0.31**
  - **Inner cylinder close out weld 0.116**

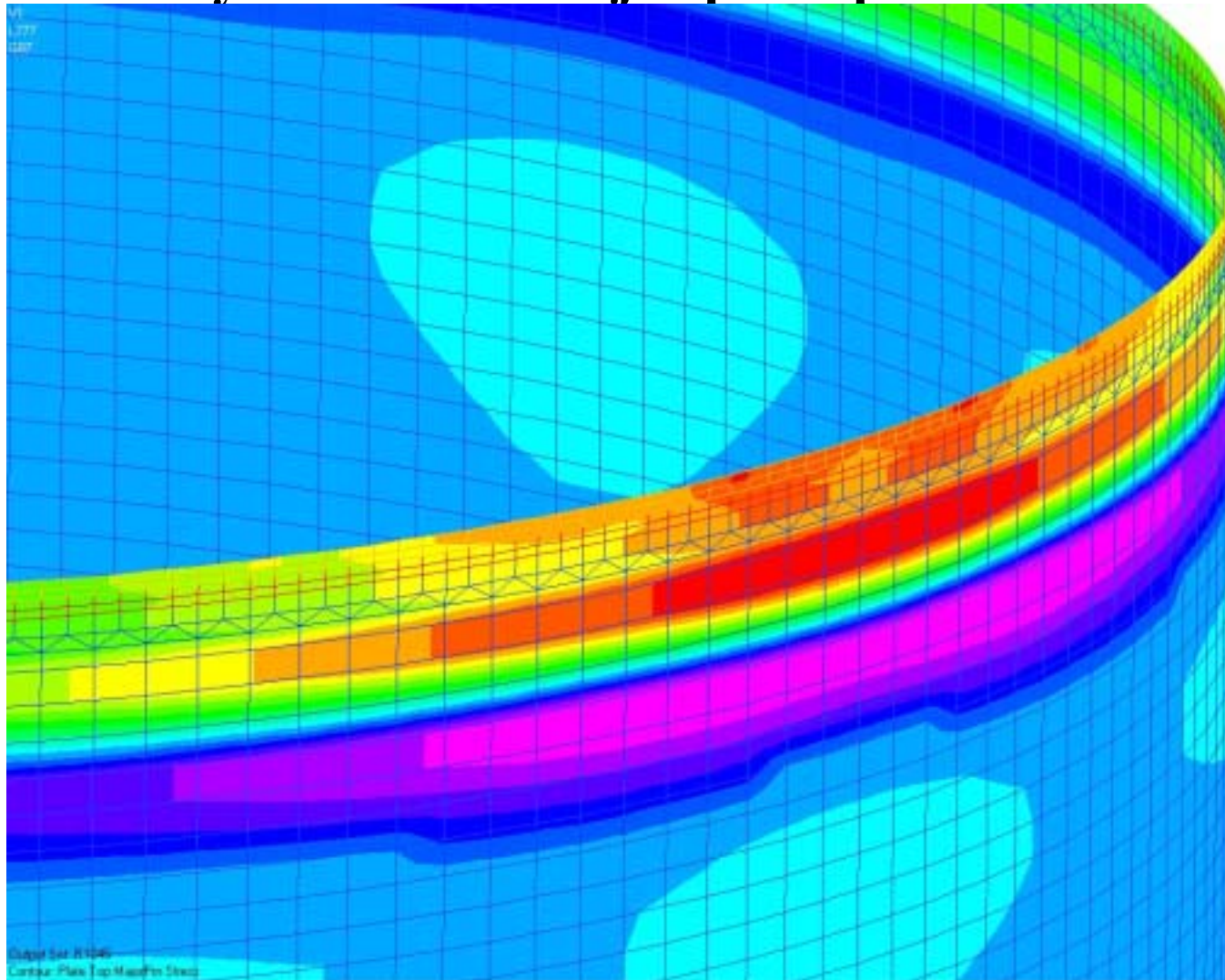




- Inner cylinder minor principal stress = 31393 psi



- Inner Cylinder weld major principal stress = 19666 psi

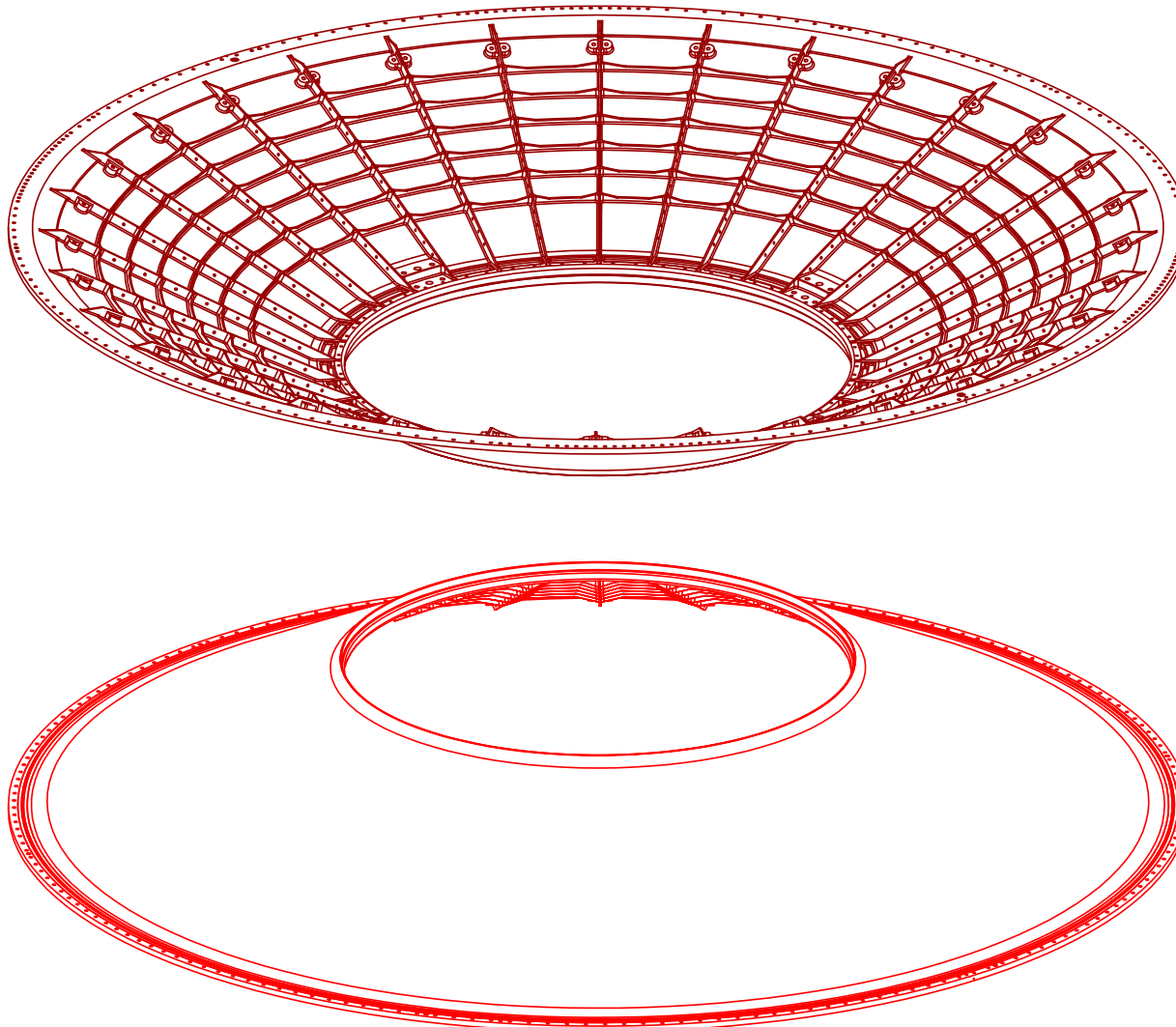


## AMS-02 Integration Hardware (Cont)

- **Conical Flange**

- **Conical Flange consists of 32 radial ribs and 6 circumferential ribs**
- **Skin thickness 0.095 in., Radial ribs 0.140 to 0.160 in., Circ. Ribs 0.135 to 0.150 in. thick**
- **Material 2219-T62 plate**
- **Minimum Margins of Safety:**
  - radial ribs      0.30 (ult)**
  - 0.14 (yield)**

- **Conical Flange (cont)**



# AMS-02 Integration Hardware (Cont)

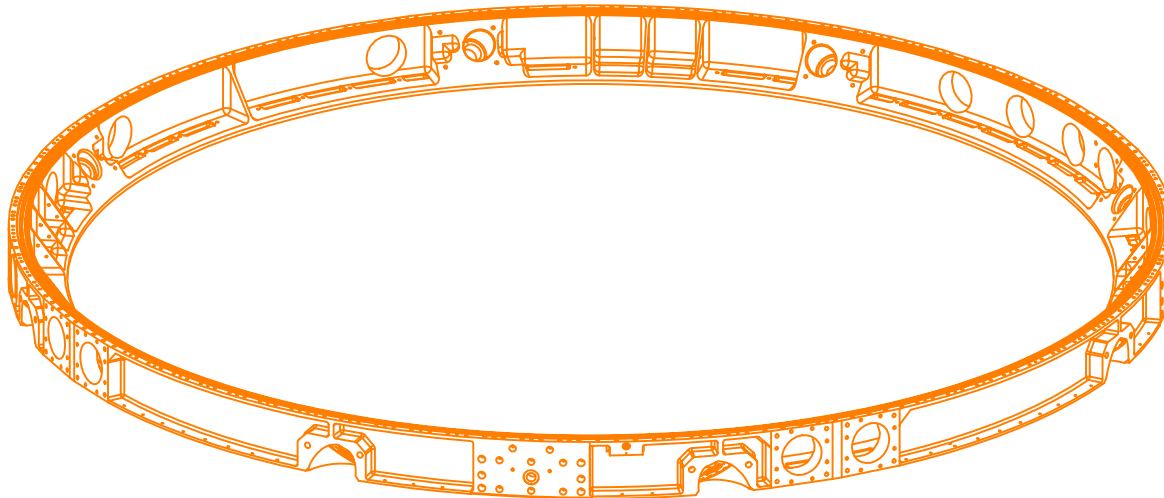
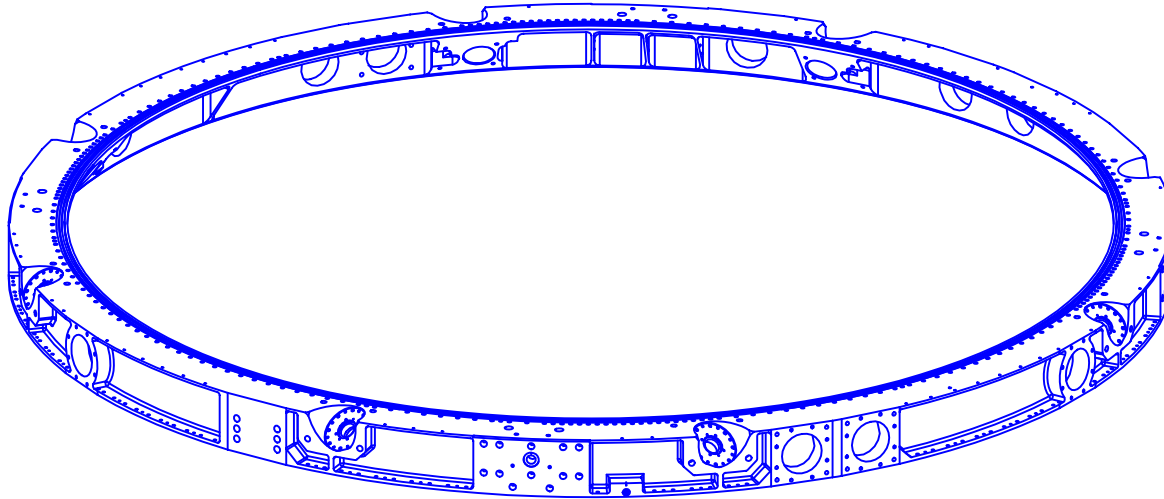
- **Conical Flange (cont)**
  - **Conical flanges are attached to the support rings with 0.25 in. bolts**
  - **Upper conical flange has 232 bolts**
  - **Lower conical flange has 192 bolts**
  - **Minimum ultimate Margin of Safety for bolts:**

<b>Upper conical flange</b>	<b>0.13</b>
<b>Lower conical flange</b>	<b>0.24</b>

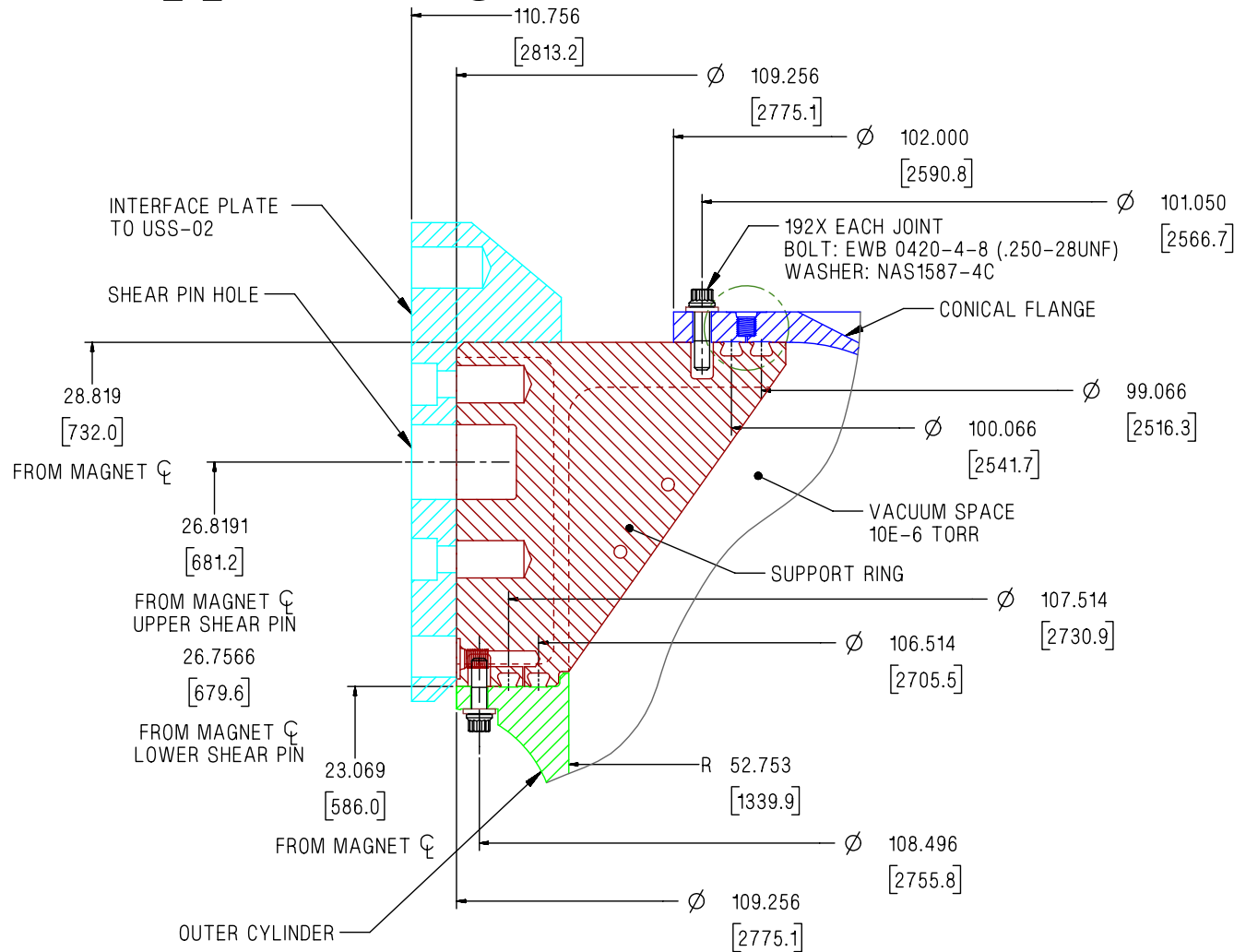
## AMS-02 Integration Hardware (Cont)

- **Support Rings**
- **Support rings are machined from 7050-T7451 ring forgings**
- **Areas for attachment of Interface plates are solid and other areas are a 'J' cross section**
- **Two O-rings are installed on each flange of the 'J' section**
- **Several ports are machined on ring. Strap ports, Feed thru ports, Helium fill ports, cryocooler ports etc. Ports have reinforcements**

- **Support Rings (cont)**



# Support Rings (cont)



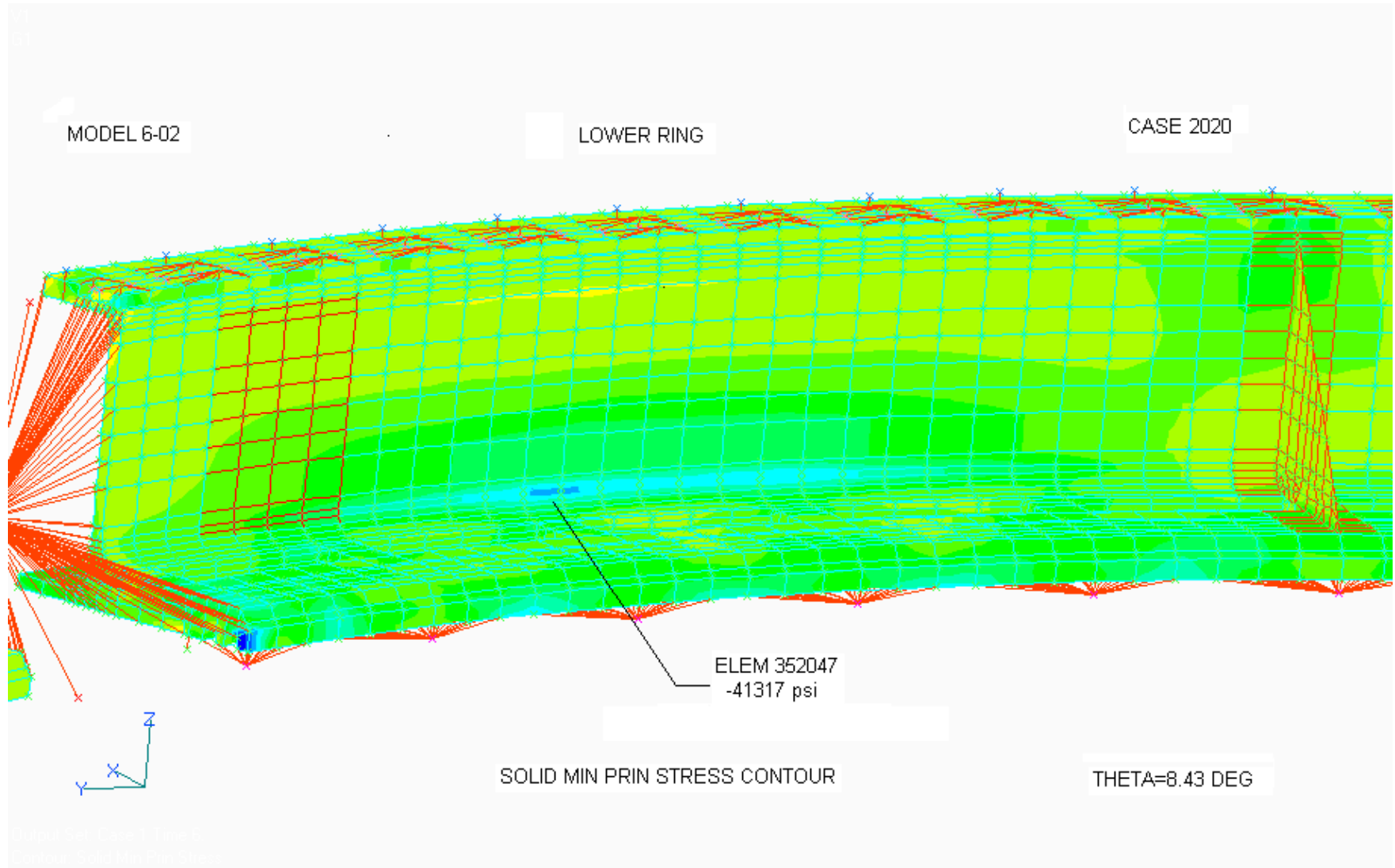
# AMS-02 Integration Hardware (Cont)

- **Support Rings (Cont)**
- **Upper Ring :**
  - **Min. principal stress                      39700 psi**
  - **Von Mises stress                              37700 psi**
  - **Minimum Margins of Safety:**
    - 0.07 (ult)**
    - 0.21 (yield)**

# AMS-02 Integration Hardware (Cont)

- **Support Rings (Cont)**
- **Lower Ring:**
  - **Min. principal stress**                      **41317 psi**
  - **Von Mises stress**                              **36600 psi**
  - **Minimum Margins of Safety:**
    - 0.03 (ult)**
    - 0.24 (yield)**

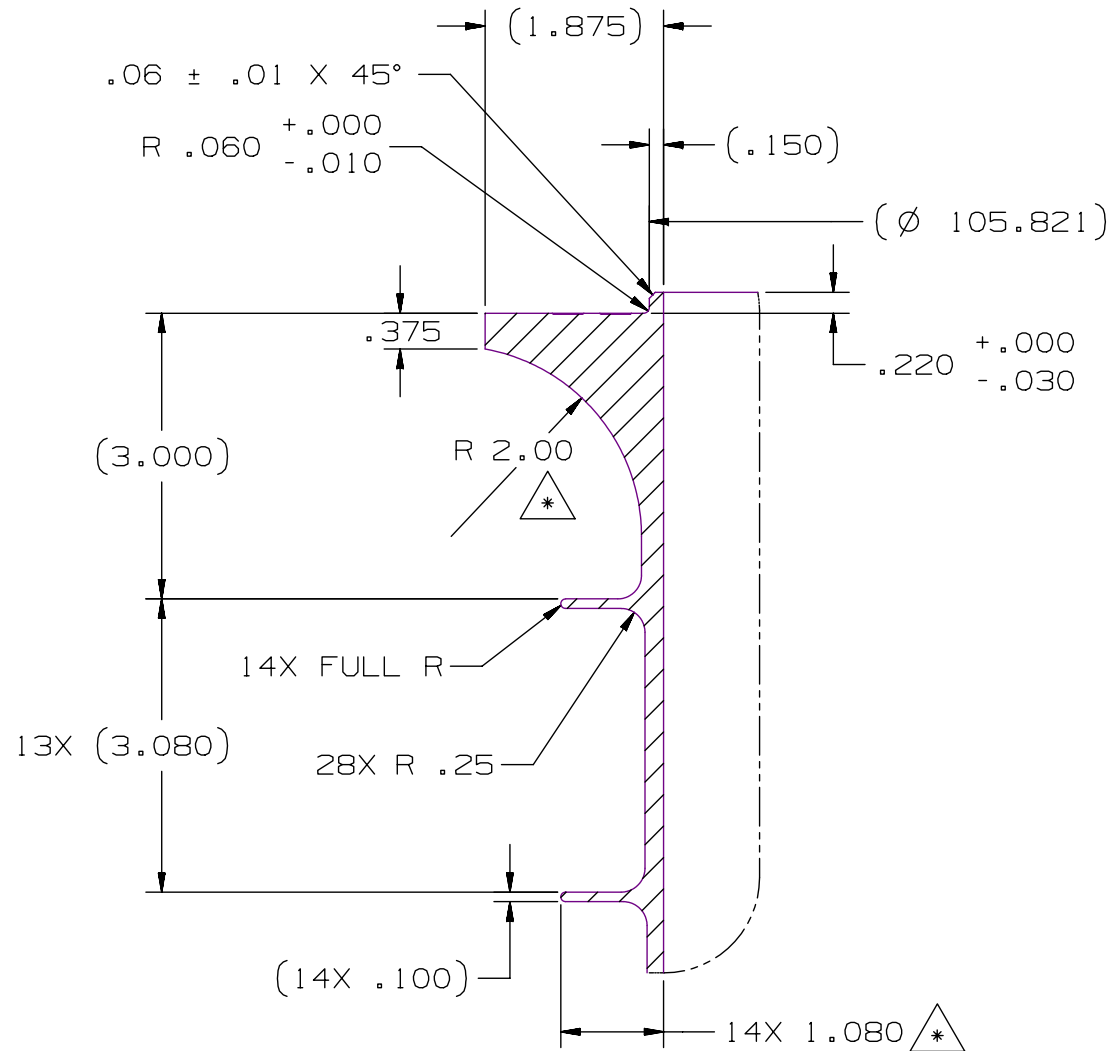
- **Min. principal stress = 41317 psi**



## AMS-02 Integration Hardware (Cont)

- **Outer Cylinder**
- **Outer cylinder is machined from a 7050-T7451 ring forging**
- **Cylinder has 14 circumferential rings and 2 flanges, integrally machined**
- **Rings are 0.10 in. thick and 1.08 in. high. Skin thickness varies between 0.152 in. to 0.265 in.**
- **Point-by-point analysis performed for all load cases for both general and local stability**
- **Local load distribution from finite element (FE) analysis is assumed to be constant throughout the structure for general stability computations at that point in the structure**

# • Outer Cylinder (cont)



## AMS-02 Integration Hardware (Cont)

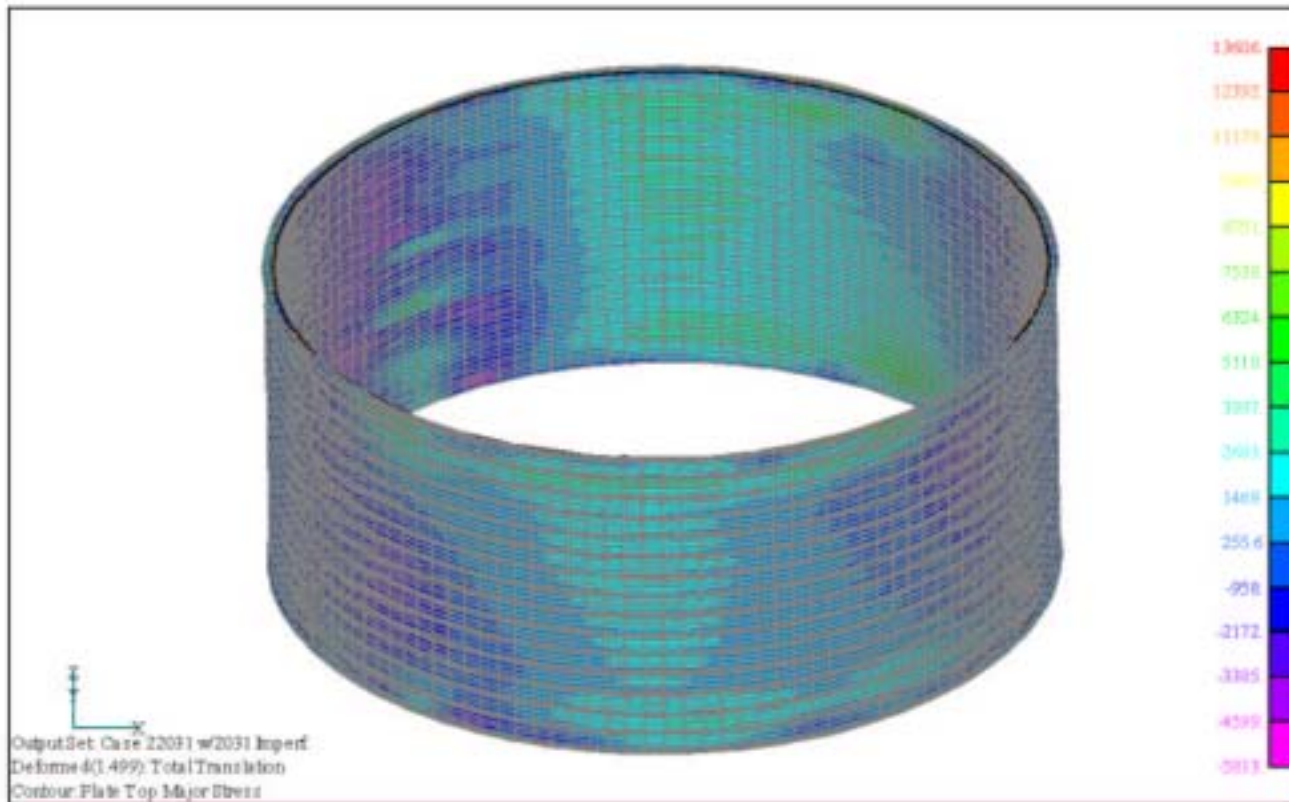
- **Outer Cylinder (cont)**
- **Analysis includes eccentricities, geometric imperfections, combined loading, and knock down factors**
- **The critical cases are identified and chosen for non-linear buckling analysis**
- **Finite element geometrically non-linear analysis is done for the critical cases for both perfect and imperfect structure**
- **Imperfect structure includes geometric imperfections with amplitudes typical of a cylinder with equivalent radius to thickness ratio and knock down factors**

## AMS-02 Integration Hardware (Cont)

- **Outer Cylinder (Cont)**
- **Structural components are considered to be unstable when small load increments will induce the structure to change configuration**
- **Geometric imperfections may have a significant influence on the buckling load**
- **This can be accounted for by the conservative application of knock down factors or inclusion of imperfections in the geometrically non linear analysis**
- **The FE non linear imperfect structure analysis is a comprehensive and more general approach and corresponds to the use of knock down factors to the linear bifurcation analysis results**

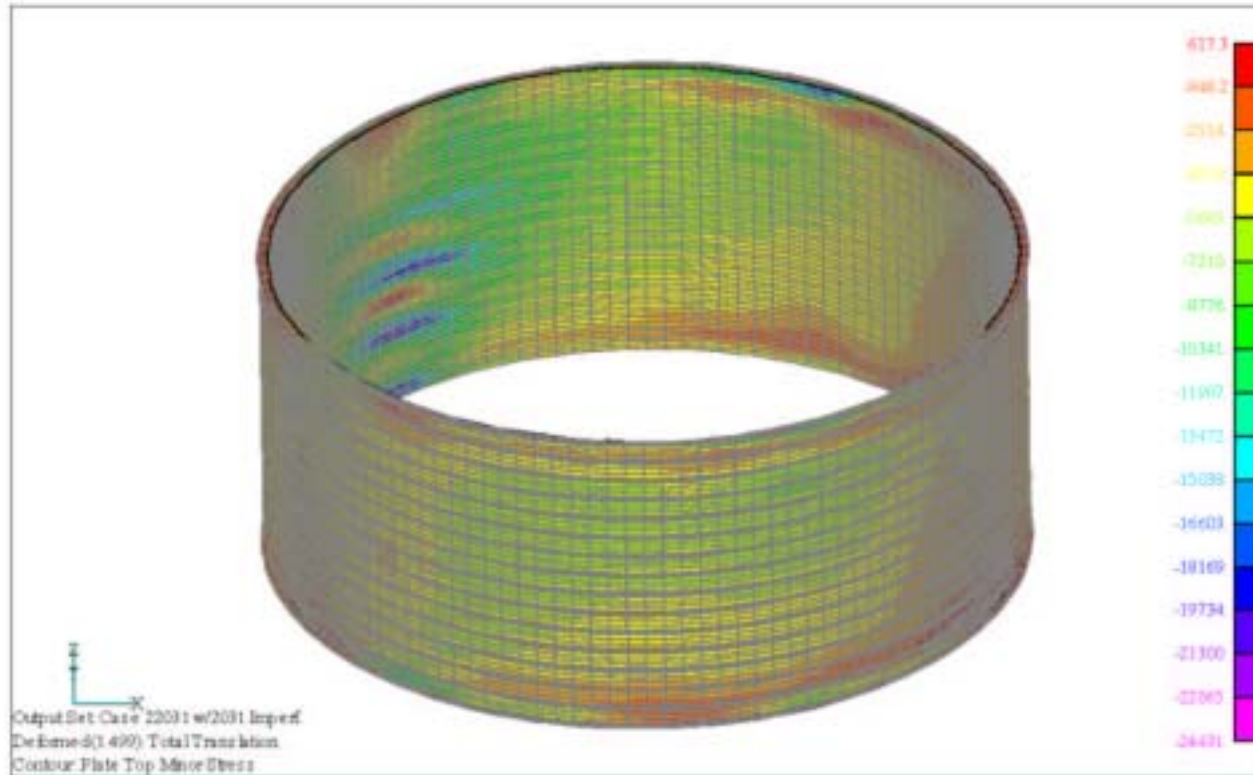
- Top major stress = 13606 psi

# Case 2031 w/2031 Imperfection Top Major SF=2.0



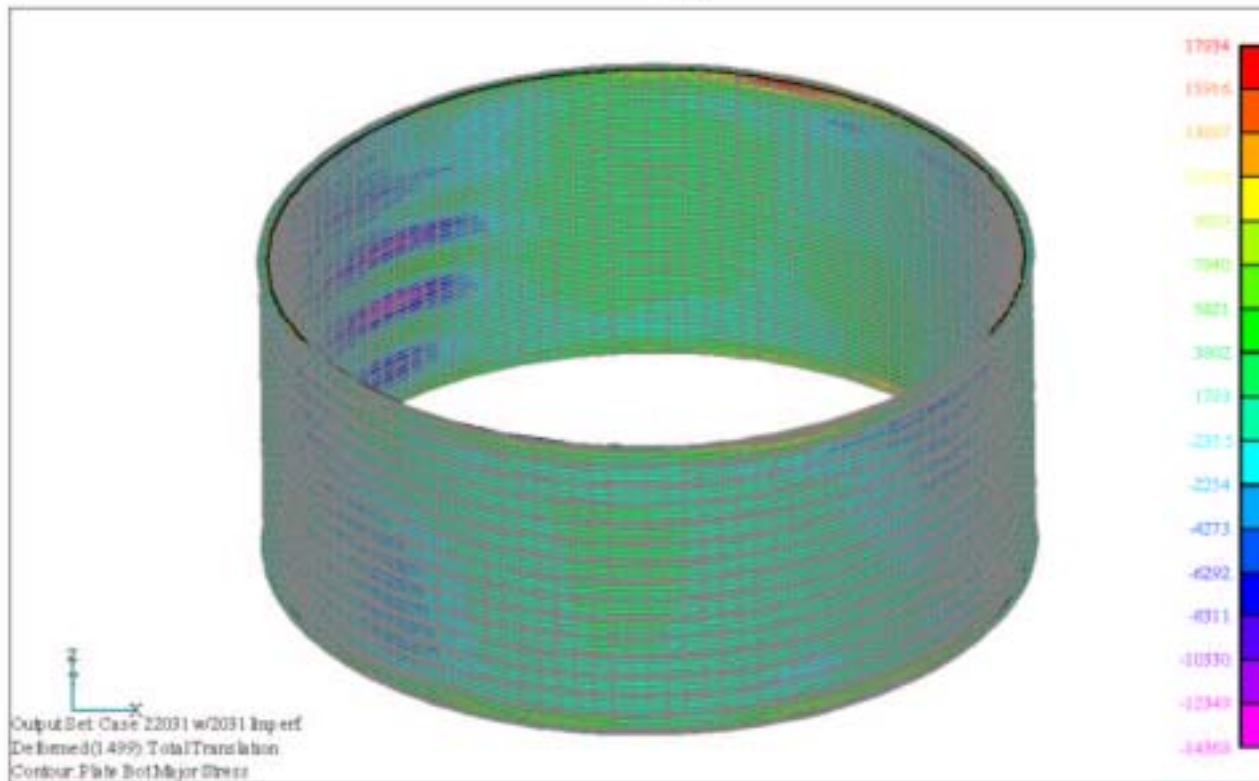
- Top minor stress = 24431 psi

# Case 2031 w/2031 Imperfection Top Minor SF=2.0



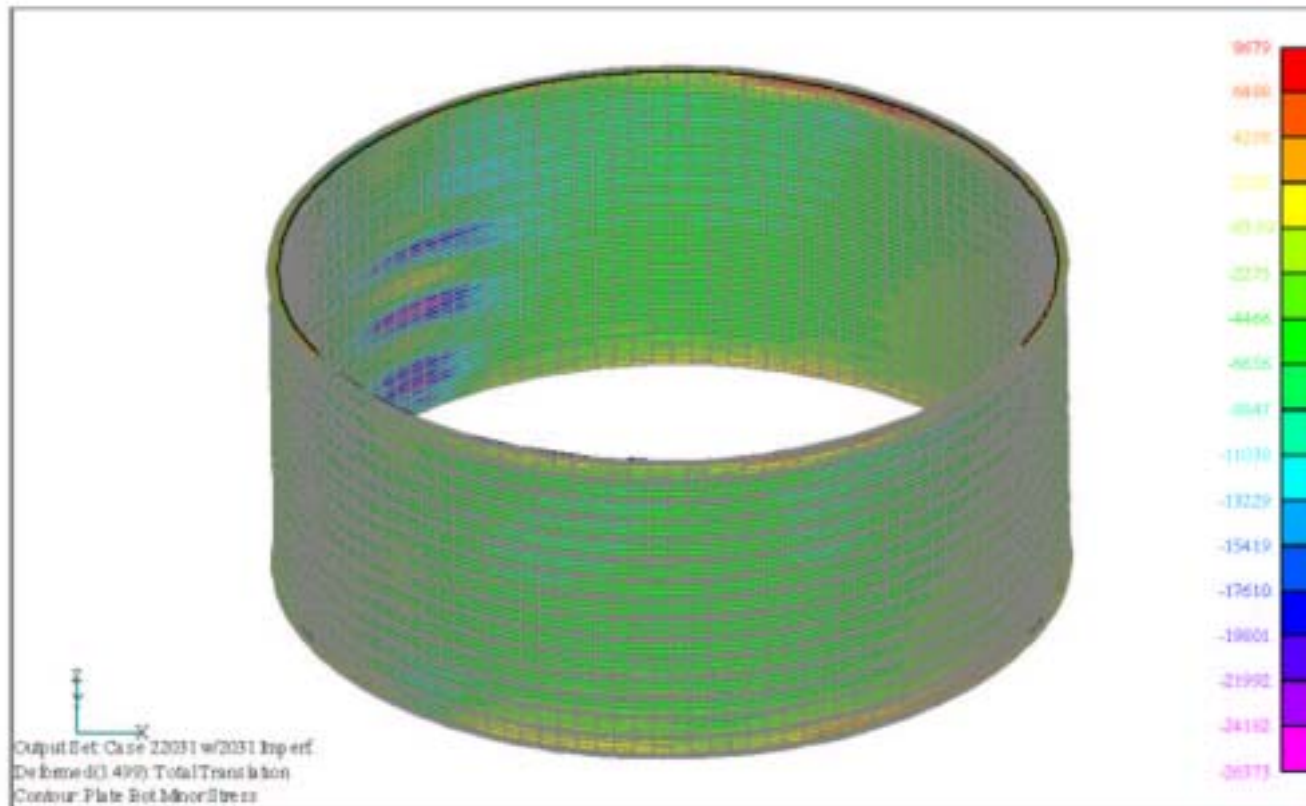
- Bottom major stress = 17934 psi

Case 2031 w/2031 Imperfection  
Bottom Major SF=2.0



- Bottom minor stress = 26373 psi

Case 2031 w/2031 Imperfection  
Bottom Minor SF=2.0



# AMS-02 Integration Hardware (Cont)

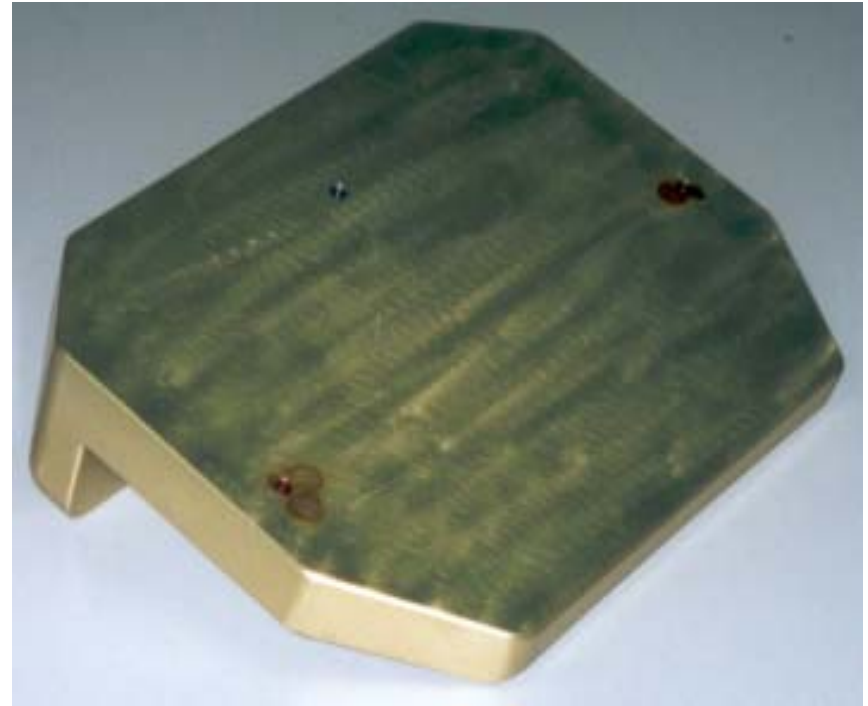
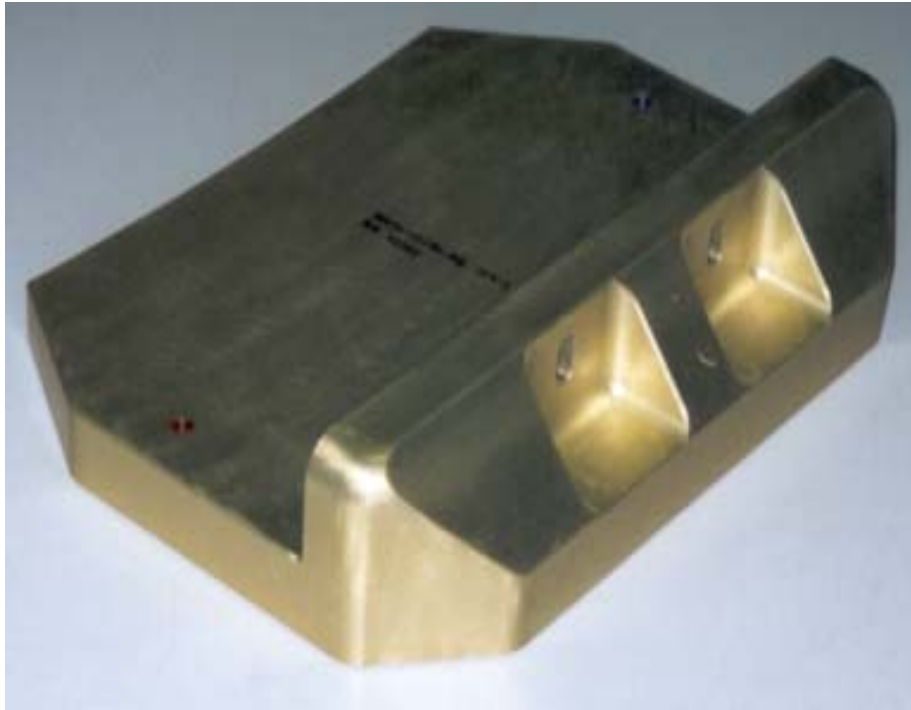
- **Outer cylinder (cont)**
- **Outer cylinder flanges are bolted to the upper and lower support rings with 0.25 in. bolts**
- **Upper ring has 192 bolts and the lower ring has 200 bolts.**
- **Flanges have a 2 in. fillet radius**
- **Minimum ultimate Margins of Safety:**
  - **Upper flange                      0.29      Bending**
  - **Lower flange                      0.90      Bending**
  - **Upper flange bolts              0.11      Shear and tension**
  - **Lower flange bolts              0.16      Shear and tension**

# AMS-02 Integration Hardware (Cont)

- **Interface plate**
- **Material 7050-T7451 plate**
- **Bolt and shear pin analysis is done for regular and fail safe conditions for all load cases**
- **Analysis is done for bolts, attaching USS-02 to interface plates and I/F plates to vacuum case**
- **Minimum margin of safety is calculated for bolts, shear pin, inserts and bushings**
- **Lower interface plate will be tested to failure to validate analysis**

# AMS-02 Integration Hardware (Cont)

- **Interface plates**



# AMS-02 Integration Hardware (Cont)

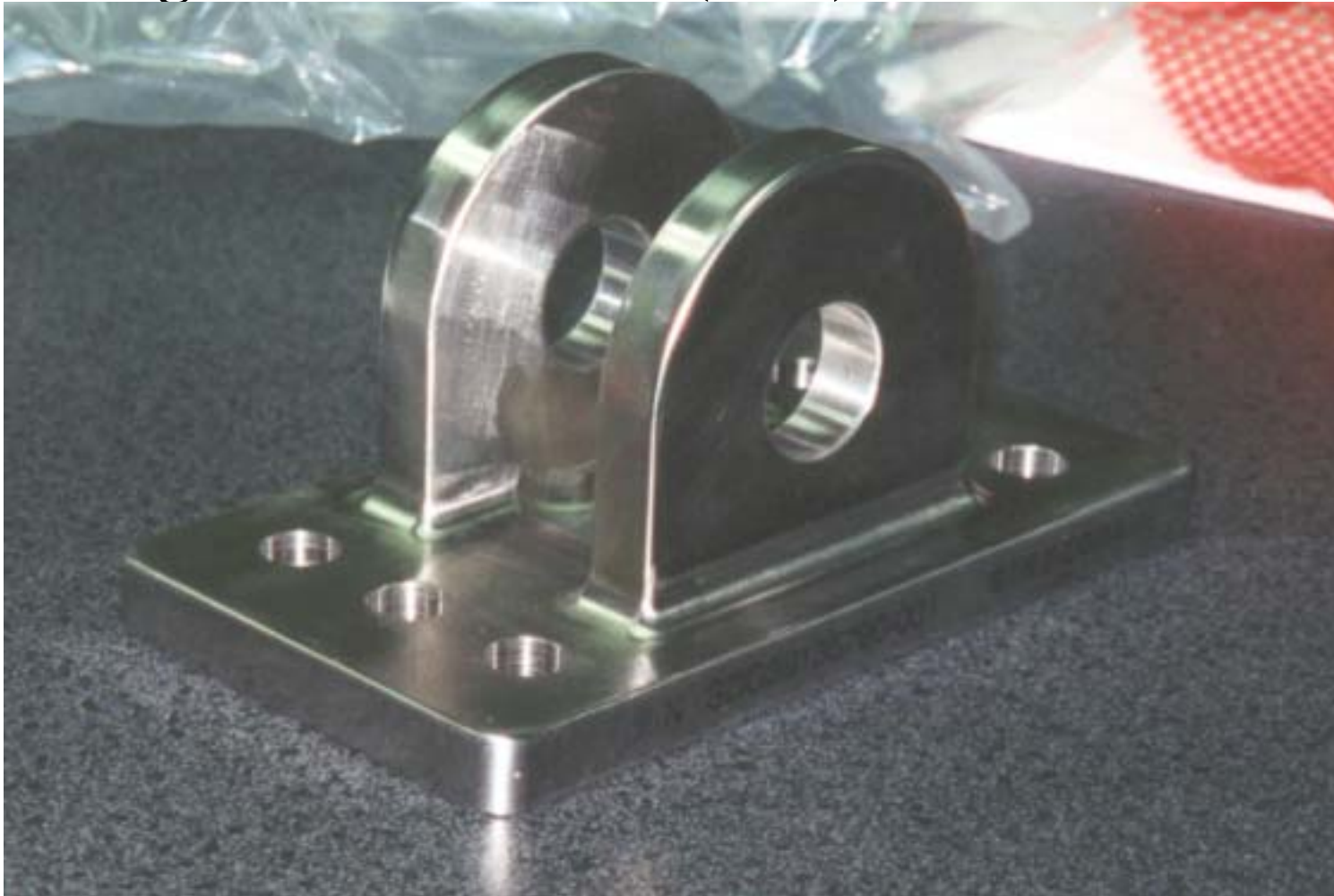
- **Interface plates (cont)**
  
- **Minimum ultimate Margins of Safety:**
  - **Bolts**                      **0.59**      **Shear and tension**
  - **Shear pin**                **0.19**      **Shear**
  - **Inserts**                    **0.71**      **Shear Pull out**
  - **Bushing**                  **0.26**      **Bearing**

# AMS-02 Integration Hardware (Cont)

- **Diagonal strut clevis**
- **Diagonal strut clevis is bolted to the upper support ring at two locations**
- **There are 6, 0.50 in. dia. bolts per clevis**
- **Material CRES A-286 plate**
- **Minimum ultimate Margin of Safety:**
  - **Bolts**                      **0.04**      **Shear and tension**
  - **Pin**                              **0.11**      **Bending**
  - **Clevis Lug**              **0.45**      **Axial and transverse loads**

# AMS-02 Integration Hardware (Cont)

- **Diagonal Strut Clevis (cont)**



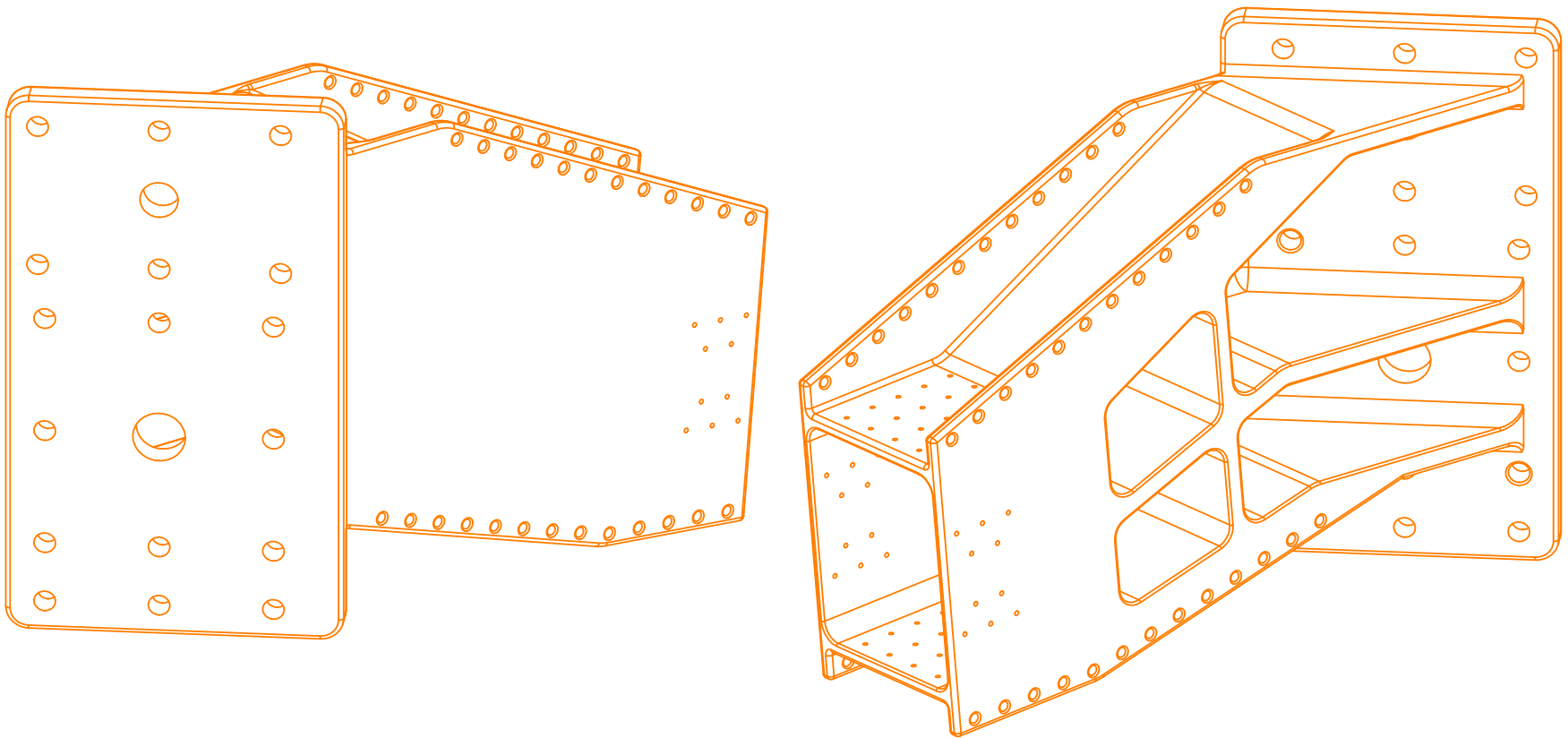
# AMS-02 Integration Hardware (Cont)

- **USS-02**
  - **Upper VC joint**
  - **Lower VC joint**
  - **USS-02 tubes**
  - **Sill Trunnion joints**
  - **Sill trunnion**
  - **Lower center body joints**
  - **Interface bolts**
  - **Keel assembly**
  - **Payload attach system (PAS) assembly**

# AMS-02 Integration Hardware (Cont)

- **Upper VC joint**
- **One of the four joints has the TRD gas system box “S” mounted on it**
- **Upper VC joint is machined from 7050-T7451 plate**
- **Base plate of joint is bolted to the upper interface plate and other end is riveted to the upper trunnion bridge**
- **Base plate also has the attachment for the TRD “M” structure**
- **Minimum ultimate Margin of Safety is 0.04**

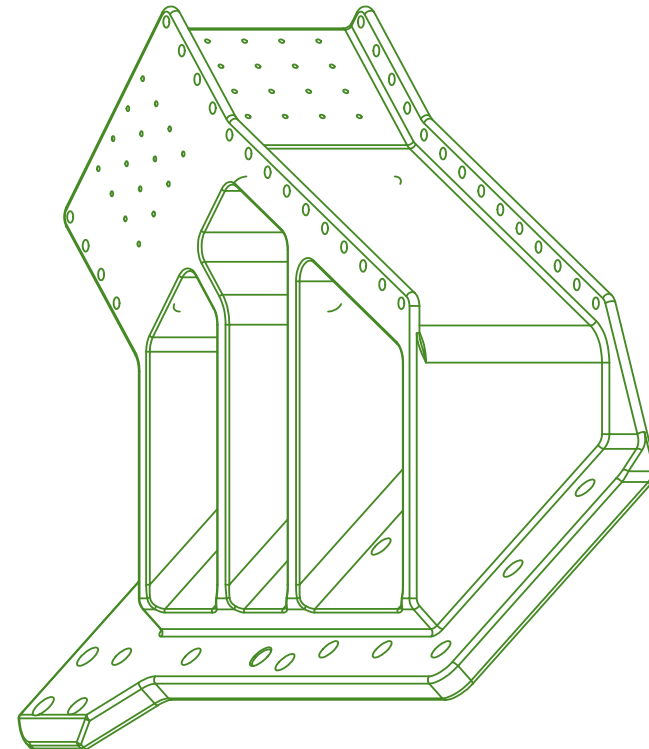
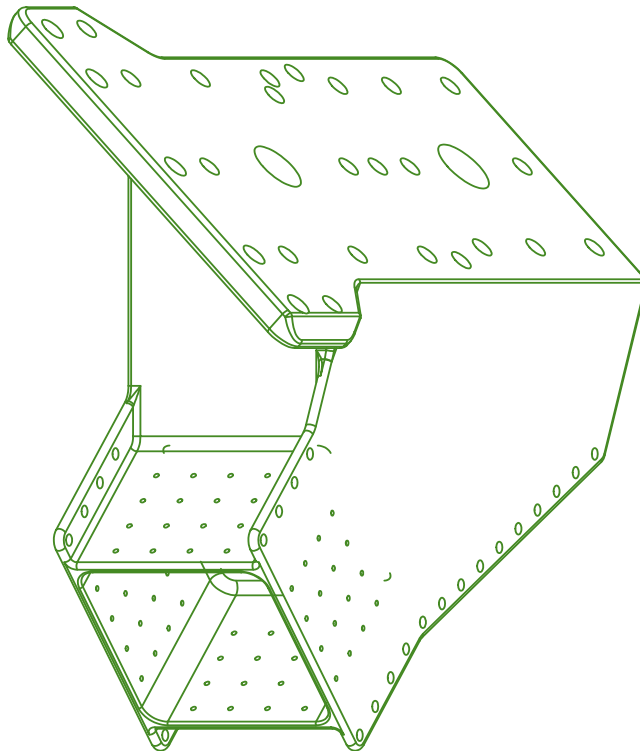
- Upper VC joint (cont)



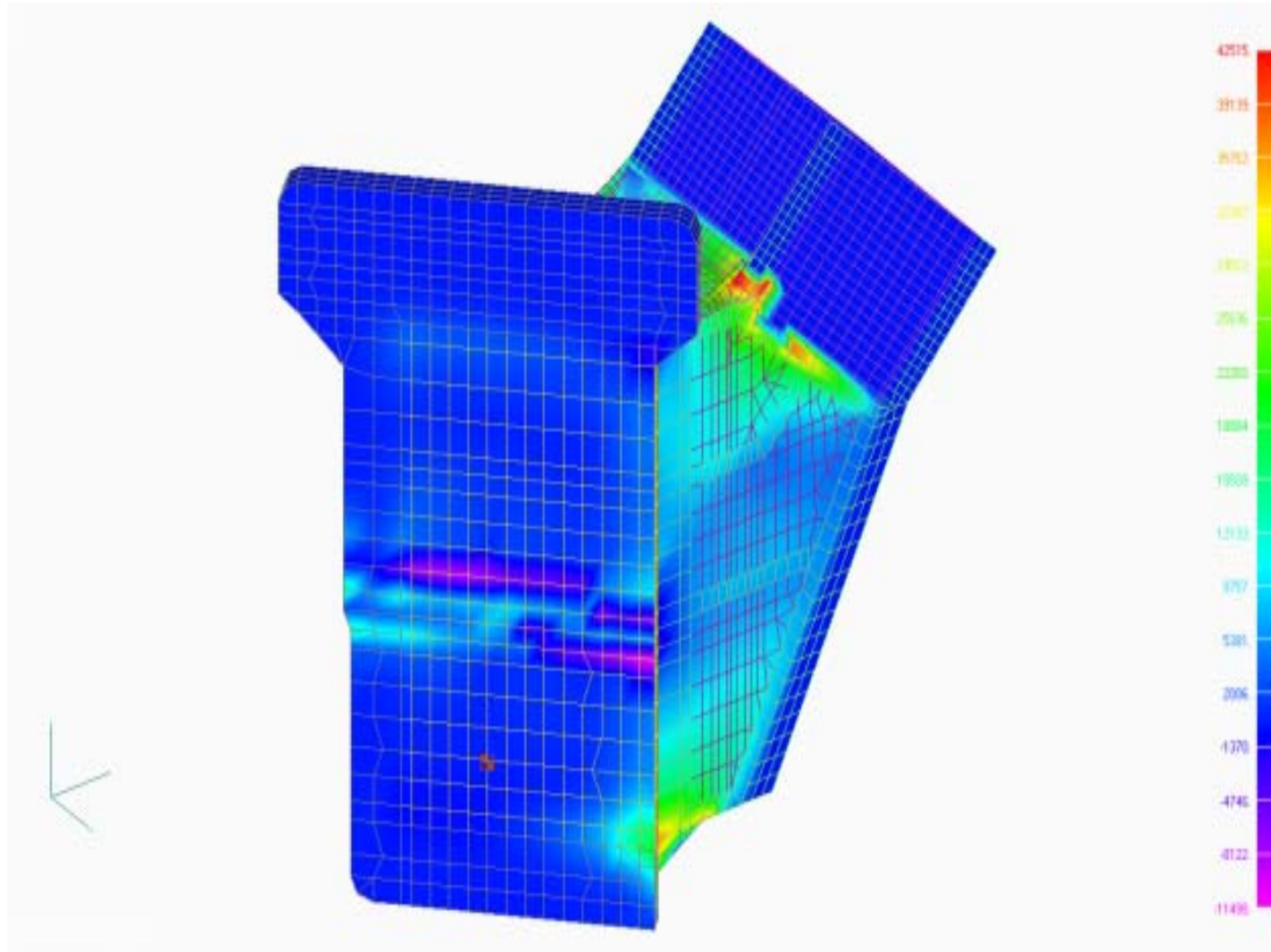
# AMS-02 Integration Hardware (Cont)

- **Lower VC joint**
- **Lower VC joint is machined from 7050-T7451 plate**
- **Base plate of joint is bolted to the lower interface plate and the other end is riveted to the lower trunnion bridge**
- **Base plate also has the attachment to the lower USS-02**
- **Minimum ultimate Margin of Safety is 0.004**
- **This joint will be static tested to failure**

- **Lower VC joint (cont)**



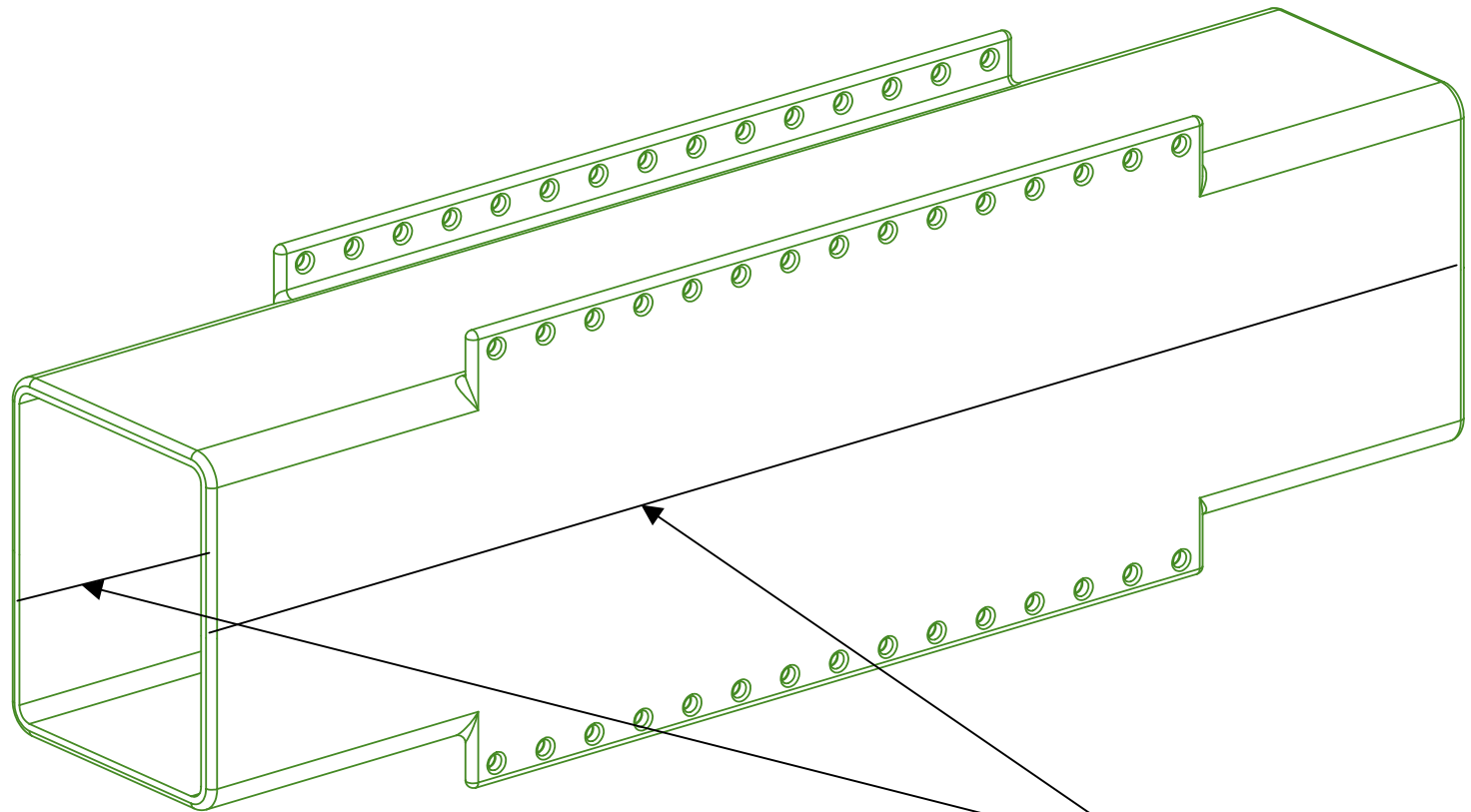
- Max. principal stress = 42515 psi



# AMS-02 Integration Hardware (Cont)

- **USS-02 Tubes**
- **Three tubes are friction stir welded, upper trunnion bridge, lower trunnion bridge and lower angle tube**
- **Material 7050-T7451 plate**
- **Analysis is done for buckling and strength using the weld properties from tests performed by LMSO and NASA**
- **Minimum ultimate Margins of Safety:**
  - **Buckling**                      **0.32 upper trunnion bridge**
  - **Strength**                      **0.93 upper trunnion bridge**

- **USS-02 Tubes**



**Weld lines**

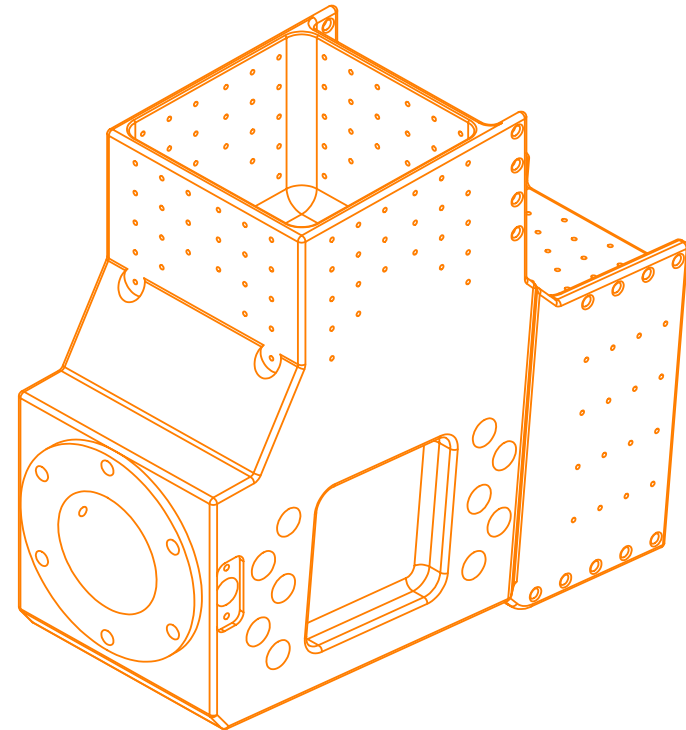
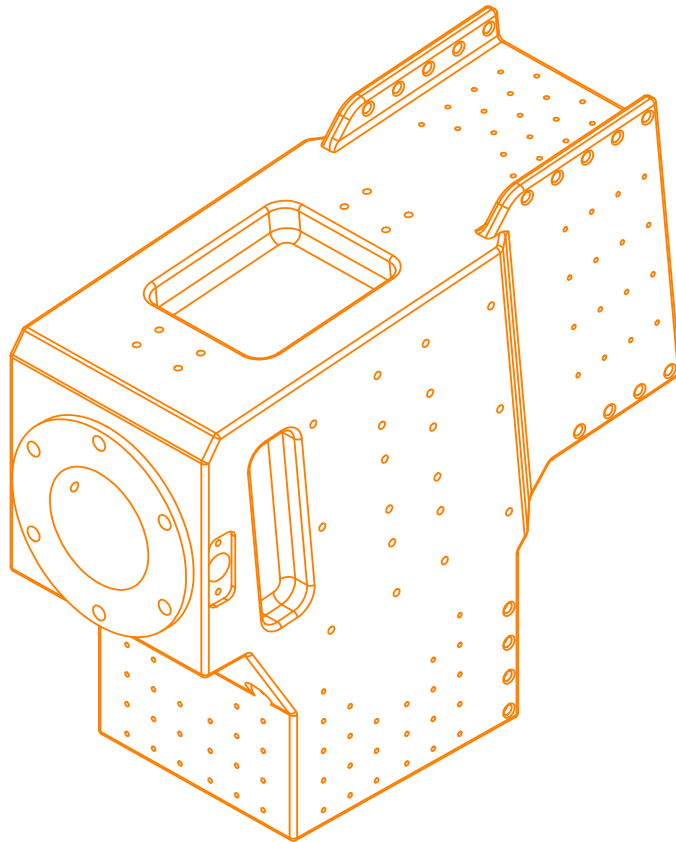
# AMS-02 Integration Hardware (Cont)

- **USS-02 Tubes (cont)**
- **Other tubes are made from existing 7075-T73511 extrusions from AMS-01**
- **Diagonal strut is made from 6061-T6511 Extrusion**
- **Minimum ultimate Margin of Safety:**
  - **Diagonal strut** **0.15**
  - **Sill tubes** **1.86**
  - **Keel tubes** **1.31**
  - **Lower center body tubes** **0.63**

# AMS-02 Integration Hardware (Cont)

- **Sill Trunnion Joint**
- **Primary and secondary sill joints are geometrically similar**
- **Loads on the primary sill joints are higher**
- **Sill joint is riveted to the upper trunnion bridge and lower trunnion bridge with an elbow joint**
- **Sill bracket is bolted to the sill joint**
- **Minimum ultimate Margin of Safety is 0.63**

- **Sill Trunnion Joint**



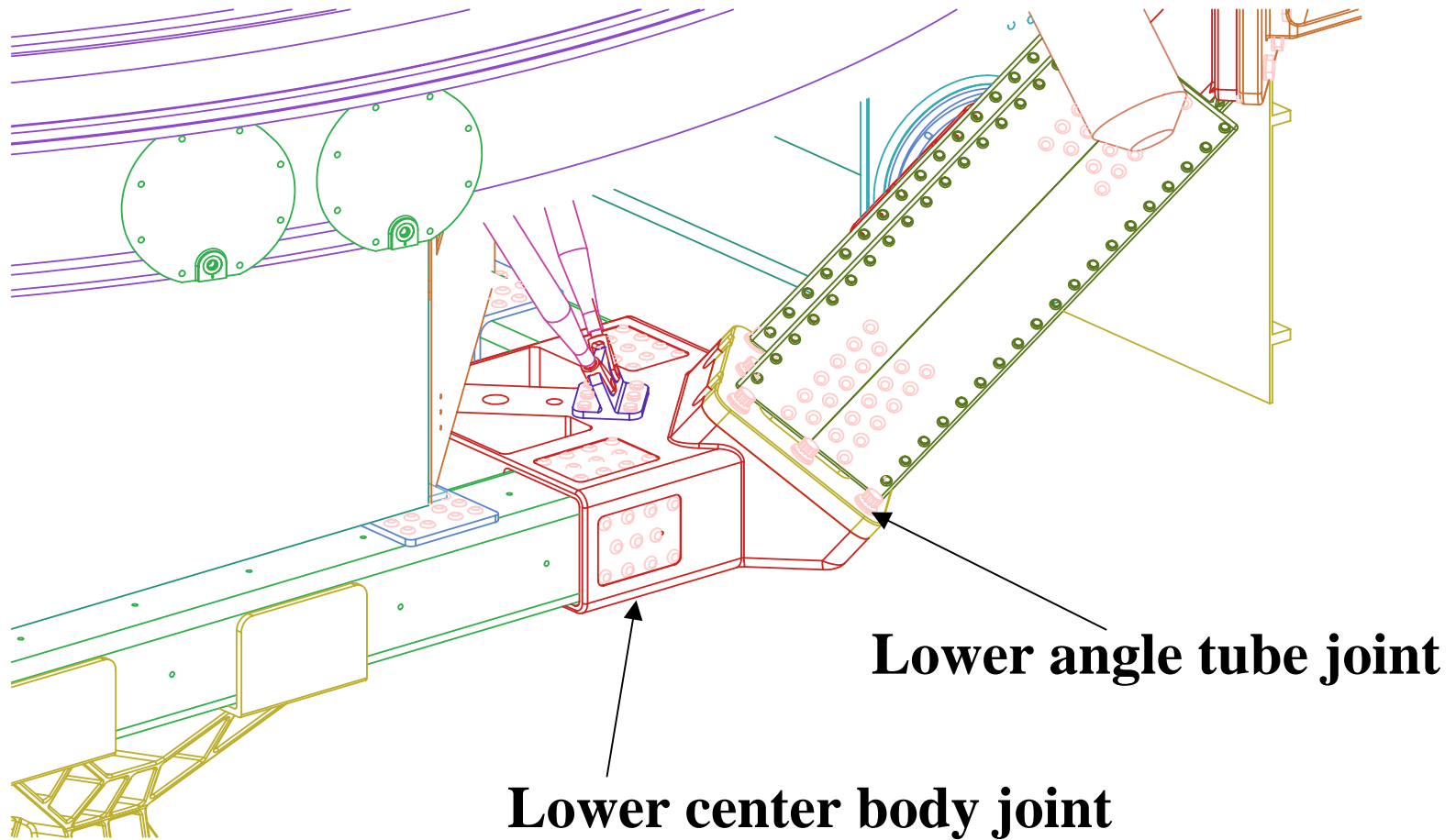
# AMS-02 Integration Hardware (Cont)

- **Sill Trunnions**
- **Sill trunnions are attached to the sill joints with a push fit**
- **Material Custom 455 H1000 steel bar**
- **Trunnions are retained by 0.25 in. pins**
- **Scuff plates are bolted to the sill joint to protect the trunnions**
- **Analysis is done with the max. trunnion loads sorted from all load cases**
- **Minimum Margin of Safety:**
  - **Ultimate**                      **0.18 bending**
  - **Yield**                              **0.05 bending**

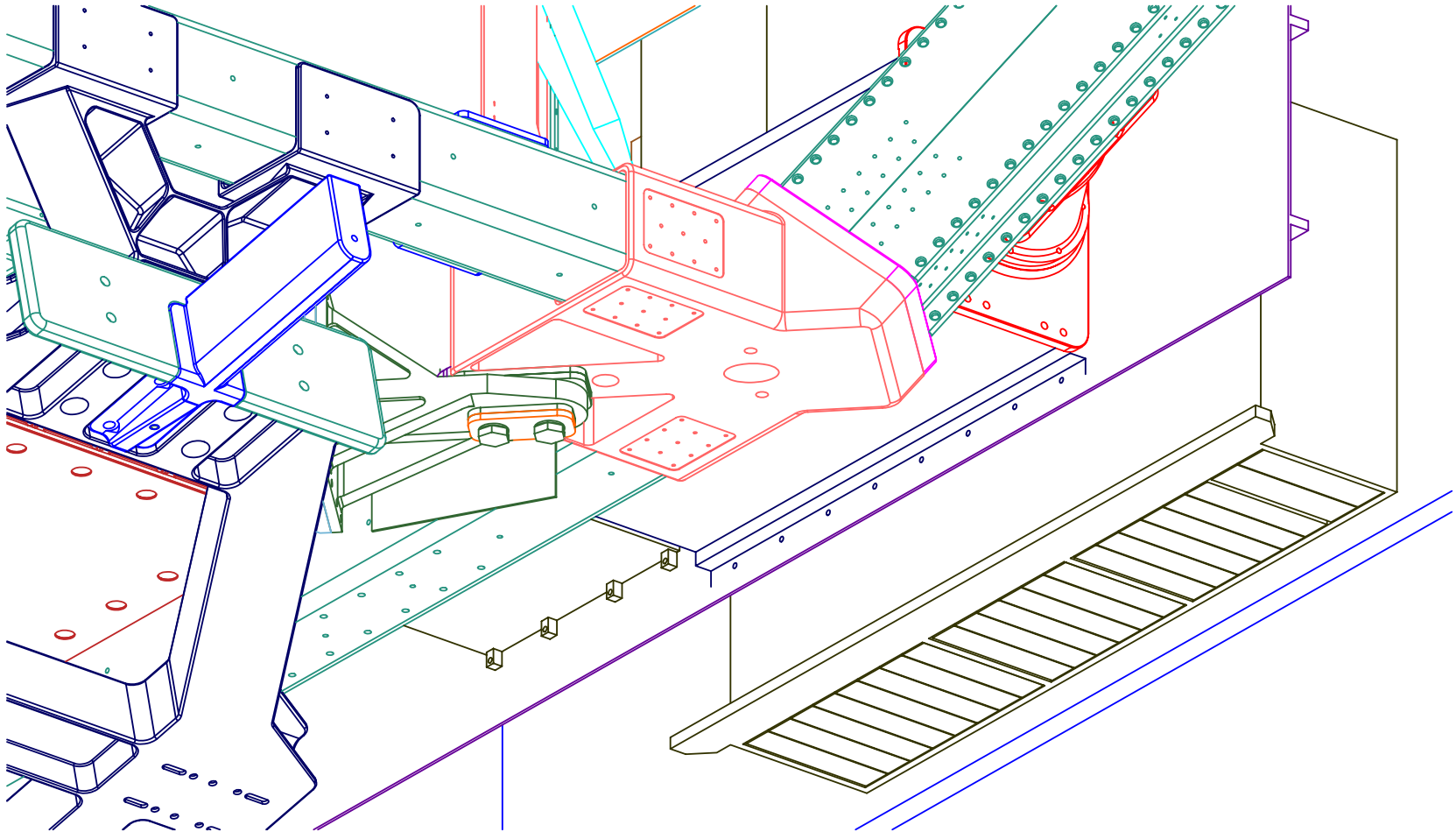
# AMS-02 Integration Hardware (Cont)

- **Lower center body joint**
- **Material 7050-T7451 plate**
- **Center body joint provides connection for the ECAL, RICH, Lower TOF struts, PAS, Lower angle tube joint, and center body tubes**
- **Two joints have connections to the keel assembly**
- **Minimum ultimate Margin of Safety is 0.18**

- **Lower Center body joint (cont)**



- **Lower center body (cont)**



# AMS-02 Integration Hardware (Cont)

- **Interface bolts**
- **Bolt analysis is done for all load cases for regular and fail-safe conditions for all bolted joints**
- **TRD to USS-02 bolts**
  - **6 bolts, and one shear pin 0.50 in dia.**
  - **Minimum ultimate Margin of Safety:**
  - **Bolts                      0.47**
  - **Shear pin                0.26**
  - **Nuts                        1.50**

# AMS-02 Integration Hardware (Cont)

- Interface bolts (cont)
- **Lower USS-02 to Upper USS-02 bolts**
  - 8 bolts 0.5 in. dia. and one shear pin 0.875 in dia.
  - **Minimum ultimate Margins of Safety:**
  - **Bolts                      0.76**
  - **Shear pin                0.95**
  - **Nuts                      0.41**

# AMS-02 Integration Hardware (Cont)

- **Interface bolts (cont)**
- **Lower angle tube joint flange bolts**
  - **8 bolts 0.5 in. dia.**
  - **Minimum ultimate Margins of safety:**
  - **Bolts                      0.29**
  - **Inserts                    0.09**

# AMS-02 Integration Hardware (Cont)

- **Keel assembly**
- **Keel assy consists of a keel block, keel trunnion, two keel tubes and two keel angle joints**
  - **Keel block**                      **7050-T7451 plate**
  - **Keel trunnion**                **Custom 455, H1000 steel bar**
  - **Keel tubes**                    **7075-T73511 Extrusions**
  - **Keel angle joints**            **7050-T7451 plate**
  - **Keel angle joint to lower center body 7 bolts 0.50 in. dia. A-286 bolts**

# AMS-02 Integration Hardware (Cont)

- **Keel assembly (cont)**
- **Minimum margins of safety:**
  - **Keel Block** **0.07 ultimate**
  - **Keel Trunnion** **0.19 yield**
  - **Keel tubes** **1.31 ultimate**
  - **Keel angle joint in work . M.S. expected to be high**
  - **Keel angle to lower center body joints**  
**0.48 ult. bolts**  
**0.06 ult. inserts**

# AMS-02 Integration Hardware (Cont)

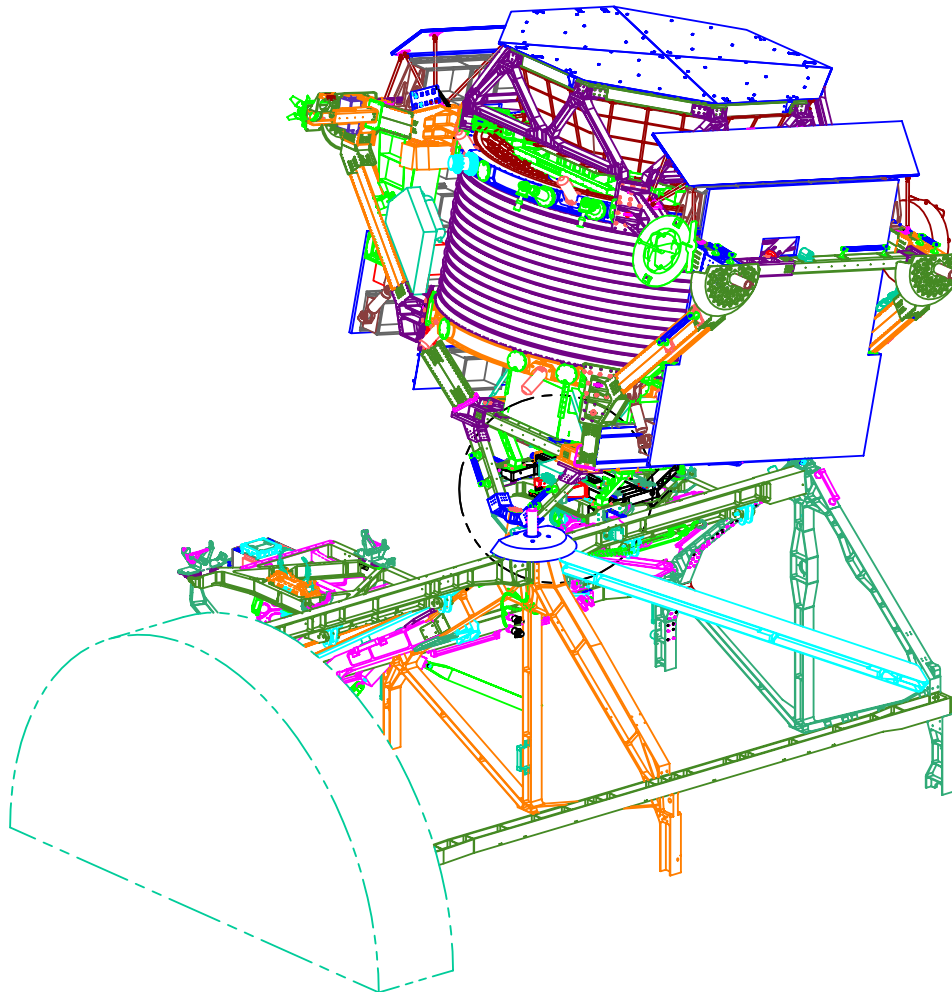
- **Rivets**

- **Rivets are used to attach several of the tubes to joints**
- **Both aluminum and Monel blind rivets are used depending on the loads in the joint**
- **Rivets are 0.25 in dia. NAS 1398D or NAS 1398M**
- **Rivet analysis is done for all joints based on critical load cases as sorted from beam loads**
- **Axial loads, shear loads, bending moments and torsion is used for the analysis**
- **Minimum ultimate Margin of Safety is 0.16**

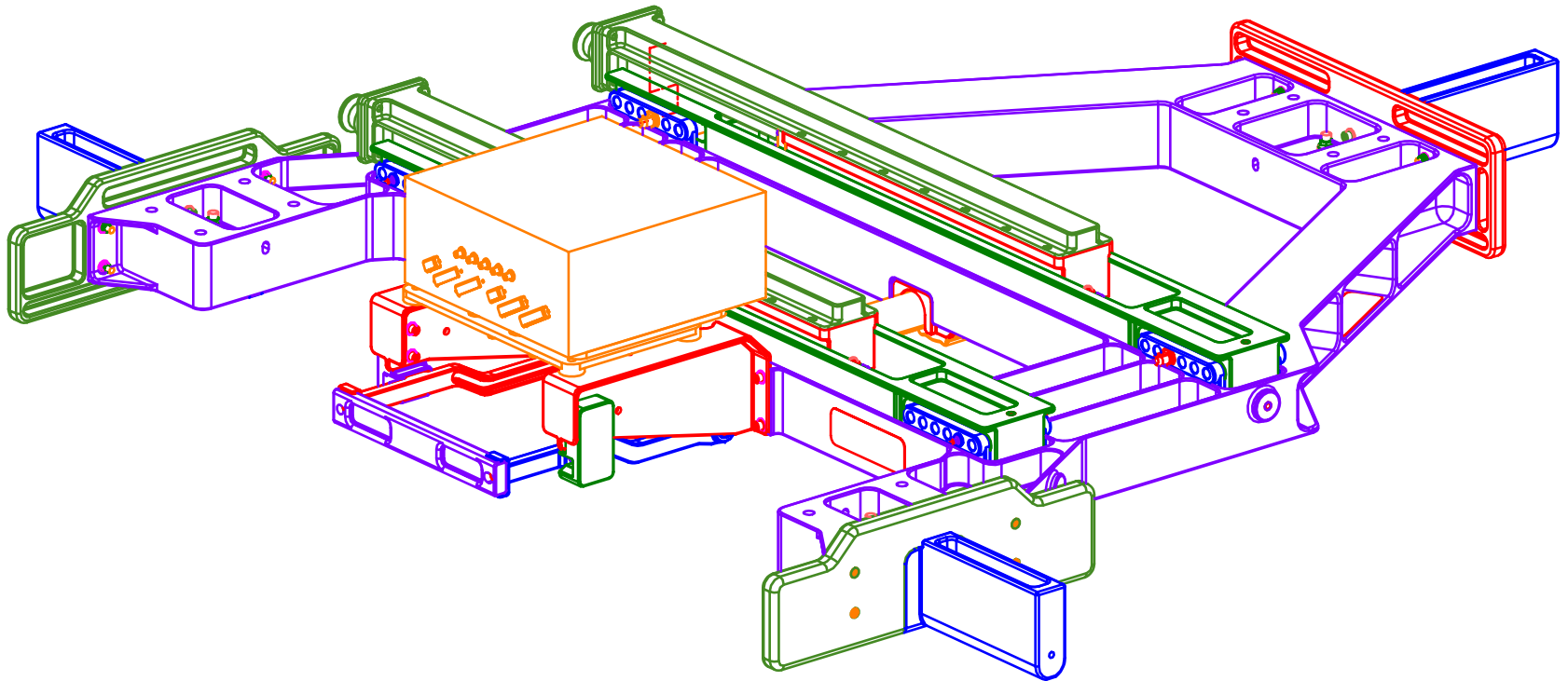
# AMS-02 Integration Hardware (Cont)

- **Payload attach system (PAS)**
- **PAS is used to attach the AMS-02 payload to the Space station**
  - **Major components of the PAS assembly are:**
    - **PAS platform**
    - **Guide pins**
    - **Capture bar**
    - **Bridge beam**
    - **Bearing housing**

- **Payload Attach System (PAS)**



- **Payload attach System (PAS) (cont)**



# AMS-02 Integration Hardware (Cont)

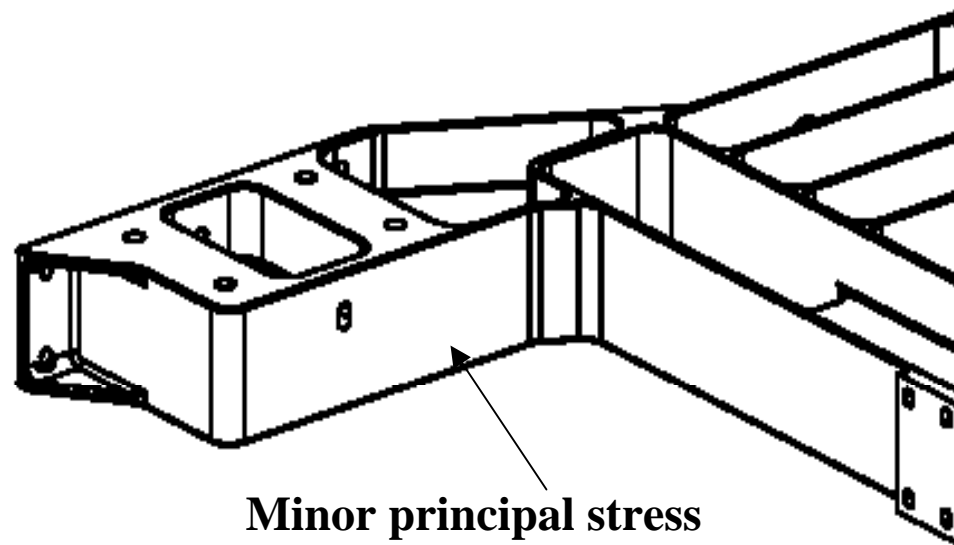
- **Payload attach system (PAS) (cont)**
  - **Lift-off, landing, On-orbit and capture bar loads are used for analysis**
  - **Factors of safety 2.0 ultimate and 1.25 yield**
  - **Each bridge beam has six pin locations at each end**
  - **The pin positions are adjustable to obtain overall interface stiffness**

# AMS-02 Integration Hardware (Cont)

- **Payload attach system (PAS) (cont)**
- **Minimum margins of safety:**
  - **Platform** **0.07**
  - **Guide pins** **High**
  - **Capture bar** **0.05**
  - **Bridge assembly** **0.08**
  - **Bearing housing** **0.25**

# AMS-02 Integration Hardware (Cont)

- **Payload attach system (PAS) (cont)**



- Payload attach system (PAS) (cont)
- Minor principal stress = 31339 psi

